Chapter 10 THERMODYNAMICS

Thermodynamics:

⇒ Thermodynamics is that branch of physics which is concerned with transformation of heat into mechanical work.

⇒ It deals with the concepts of heat, temperature and inter-conversion of heat into other forms of energy i.e., electrical, mechanical, chemical magnetic etc.

⇒ Thermodynamics does not take any account of atomic or molecular constitution of matter and it deals with the bulk systems.

⇒ State of any thermodynamic system can be described in terms of certain know macroscopic variables known as thermodynamic variables.

⇒ Thermodynamic variables determine the thermodynamic behavior of a system. Quantities like pressure (P), volume (V), and temperature (T) are thermodynamic variables. Some other thermodynamic variables are entropy, internal energy etc. described in terms of P, V and T.

⇒ A thermodynamic system is said to be in thermal equilibrium if all parts of it are at same temperature.

⇒ Thus, two systems are said to be in thermal equilibrium if they are at same temperature.

Heat:

⇒ Heat may be defined as energy in transit(transition)

⇒ Only heat gain or only heat lost is not possible.

⇒ Word heat is used only if there is a transfer of energy from one thermodynamic system to the another.

⇒ When two systems at different temperatures are kept in contact with each other then after some time temperatures of both the systems become equal and this phenomenon can be described by saying that energy has flown from one system to another.

⇒ The word heat is sometimes used to refer to the process by which energy is transferred between objects because of a difference in their temperatures. This textbook will use heat to refer only to the energy itself.

⇒ This flow of energy from one system to another on account of temperature difference is called heat transfer.

⇒ Flow of heat is a non-mechanical mode of energy transfer.

⇒ Heat flow depends not only on initial and find states but also on path it's.

⇒ Symbolically heat is represented by "Q".

⇒ In old physics, it is also called "caloria" because it is massless and invisible fluid. On these bases the unit of heat is based.

⇒ If temperature of system is greater than temperature of surrounding, then heat lost by system is greater than heat gained by the system. So $\Delta Q = -ve$.

⇒ If temperature of the system is less then temperature of surrounding, then it shows that heat gain by system is greater than heat loss by the system. So $\Delta Q = +ve$.

⇒ If a body gain heat then it is given by $+Q$.

⇒ If a body lost heat then it is given by $-Q$.

⇒ Heat always flow from a region of higher concentration to a region of lower concentration. So, it is called transit.

⇒ Unit: it is energy hence its unit is calories. And 1 calories = 4.18 joules.

Work in volume changes

⇒ Consider a cylinder filled with gas and equipped with a movable piston as shown in fig below

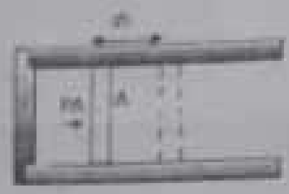


fig - Force exerted by a system during small expansion.

Suppose,

A - Cross Sectional area of cylinder

P - Pressure exerted by piston at the piston face.

PA - Force exerted by the system.

⇒ If piston moves out by a distance dx then work done by this force is dW given by

$$dW = pAdx = pdV \quad (1)$$

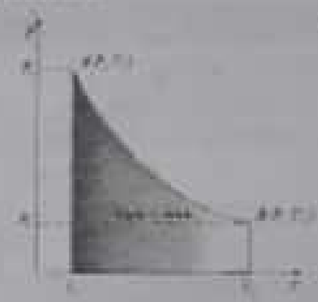
since $V = Adx$ and dV is change in volume of the system.

⇒ In a finite volume change from V_1 to V_2

$$W = \int pdV \quad (2)$$

where limits of integration go from V_1 to V_2

Graphically this relationship is shown below



⇒ Thus equation (2) can be interpreted graphically as area under the curve between limits V_1 and V_2

⇒ If pressure remains constant while the volume changes, then work is

$$W = P(V_2 - V_1) \quad (3)$$

⇒ Work done not only depends on initial and final states but also on the intermediate states i.e., on the path

P-V Indicator Diagram (Pressure and Volume curve):

⇒ Only two thermodynamic variables are sufficient to describe a system because third variable can be calculated from equation of state of the system.

⇒ P-V Indicator Diagram is just a graph between pressure and volume of a system undergoing an operation.

⇒ When a system undergoes an expansion from state A ($P_1 V_1$) to a state B ($P_2 V_2$) its indicator diagram is shown as follows.

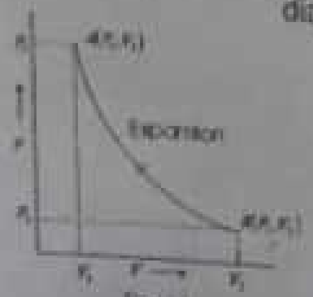


Figure 1

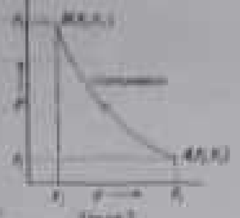


Figure 2

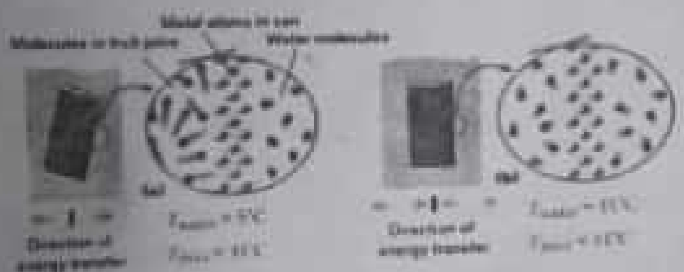
⇒ In case of compression system at state A($P_1 V_1$) goes to a state B($P_2 V_2$) its indicator diagram is as follows.

⇒ Intermediate states of system are represented by points on the curve.

⇒ The pressure volume curve for a fixed temperature is called isotherm.

HOW ENEGY TRANSFERRED AS A HEAT:

From a macroscopic viewpoint, energy transferred as heat tends to move from an object at higher temperature to an object at lower temperature. This is similar to the mechanical behavior of objects moving from a higher gravitational potential energy to a lower gravitational potential energy. Just as a pencil will drop from your desk to the floor but will not jump from the floor to your desk, so energy will travel spontaneously from an object at higher temperature to one at lower temperature and not the other way around.



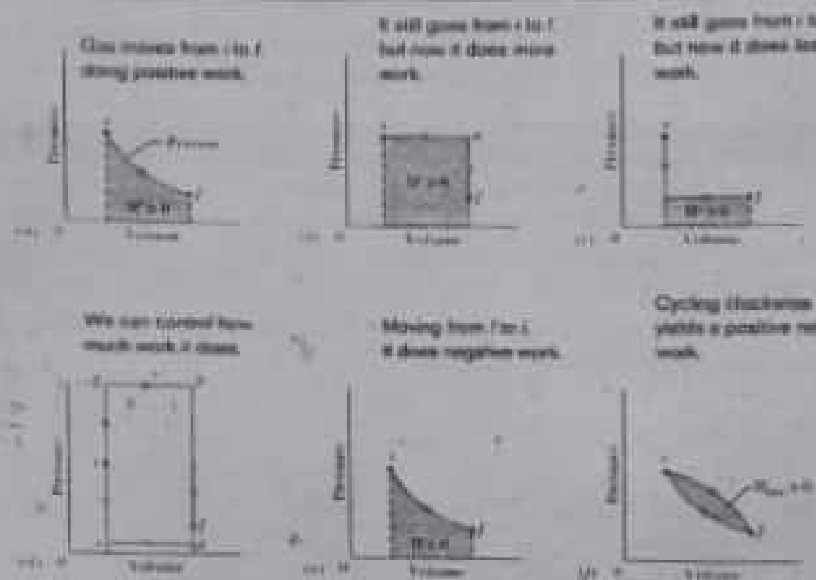
Energy is transferred as heat from the higher-energy particles to lower-energy particles **(a).** The net energy transferred is zero when thermal equilibrium is reached **(b).**
The direction in which energy travels as heat can be explained at the atomic level. Consider a warm can of fruit juice in ice water. At first, the molecules in the fruit juice have a higher average kinetic energy than do the water molecules that surround the can, as shown in **Figure (a).** This energy is transferred from the juice to the can by the juice molecules colliding with the metal atoms of the can. The atoms vibrate more because of their increased energy. This energy is then transferred to the surrounding water molecules, as shown in **Figure (b).**
As the energy of the water molecules gradually increases, the energy of the fruit juice's molecules and of the can's atoms decreases until all of the particles have, on the average, equal kinetic energies. In individual collisions, energy may be transferred from the lower-energy water molecules to the higher-energy metal atoms and fruit juice particles. That is, energy can be transferred in either direction. However, because the average kinetic energy of particles is higher in the object at higher temperature, more energy moves out of the object as heat than moves into it. Thus, the net transfer of energy as heat is in only one direction.

THERMAL UNITS AND THEIR VALUES IN JOULE:

Heat unit	Equivalent value	Uses
Joule (J)	Equal to $1\ kg.\left(\frac{m^2}{s^2}\right)$	SI unit of energy

Calorie (cal)	4.186 J	Non-SI unit of heat found especially in older works of physics and chemistry
Kilocalorie (kcal)	$4.186 \times 10^3 J$	non-SI unit of heat
Calorie or dietary calorie	$4.186 \times 10^3 J = 1\ kcal$	Food and nutritional science
British thermal unit (Btu)	$1.055 \times 10^3 J$	English unit of heat; used in engineering, air conditioning and refrigeration
therm	$1.055 \times 10^8 J$	Equal to 100 000 Btu, used to measure natural gas usage

Important Cases:



- ✓ The shaded area represents the work W done by a system as it goes from an initial state i to a final state f. Work W is positive because the system's volume increases.
- ✓ (b) W is still positive, but now greater.
- ✓ (c) W is still positive, but now smaller.
- ✓ (d) W can be even smaller (path icdf) or larger (path ighf).
- ✓ (e) Here the system goes from state f to state i as the gas is compressed to less volume by an external force. The work W done by the system is now negative.
- ✓ (f) The net-work W_{net} done by the system during a complete cycle is represented by the shaded area

Some important terms:

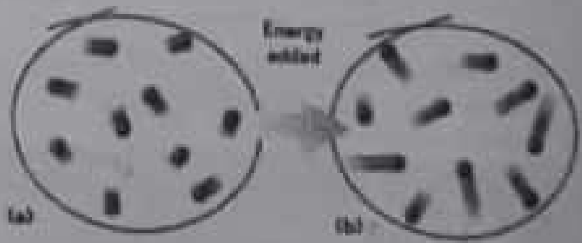
i) Temperature:

The low average kinetic energy of the particles **(a)**, and thus the temperature of the gas, increases when energy is added to the gas **(b)**.

⇒ The intensity of hotness or coldness of a body.

⇒ Temperature is measured with a thermometer, historically calibrated in various temperature scales and units of measurement.

⇒ The most commonly used scales are the Celsius scale, denoted in °C (informally, degrees centigrade), the Fahrenheit scale (°F), and the Kelvin scale



- The kelvin (K) is the unit of temperature in the International System of Units (SI), in which temperature is one of the seven fundamental base units
- Temperature is a proportional measure of the average translational kinetic energy of the random motions of the constituent microscopic particles in a system (such as electrons, atoms, and molecules), based on the historical development of the kinetic theory of gases, but more rigorous definitions include all quantum states of matter.
- A monatomic gas contains only one type of atom. For a monatomic gas, temperature can be understood in terms of the translational kinetic energy of the atoms in the gas. For other kinds of substances, molecules can rotate or vibrate, so other types of energy are also present.
- The energies associated with atomic motion are referred to as which is proportional to the substance's temperature (assuming no phase change). For an ideal gas, the internal energy depends only on the temperature of the gas.

Temperature is meaningful only when it is stable.

- **Matter expands as its temperature increases:** "Increasing the temperature of a gas at constant pressure causes the volume of the gas to increase. This increase occurs not only for gases but also for liquids and solids. In general, if the temperature of a substance increases so does its volume. This phenomenon is known as *thermal expansion*".

Specific Heat and Heat Capacity

Heat capacity:

The capability of a substance to absorb heat energy; the amount of heat required to raise the temperature of one mole or gram of a substance by one degree Celsius without any change of phase.

Heat capacity is an intrinsic physical property of a substance that measures the amount of heat required to change that substance's temperature by a given amount. In the International System of Units (SI), heat capacity is expressed in units of joules per kelvin (J K−1). Heat capacity is an extensive property, meaning that it is dependent upon the size/mass of the sample. For instance, a sample containing twice the amount of substance as another sample would require twice the amount of heat energy (Q) to achieve the same change in temperature (ΔT) as that required to change the temperature of the first sample.

Molar and Specific Heat Capacities

The amount of heat that must be added or removed from a unit mass of a substance to change its temperature by one Kelvin.

There are two derived quantities that specify heat capacity as an intensive property (i.e., independent of the size of a sample) of a substance. They are:

- the molar heat capacity, which is the heat capacity *per mole* of a pure substance. Molar heat capacity is often designated *CP*, to denote heat capacity under constant pressure conditions, as well as *CV*, to denote heat capacity under constant volume conditions.
  Units of molar heat capacity are J / K· mol
- the specific heat capacity, often simply called specific heat, which is the heat capacity per unit mass of a pure substance. This is designated c_P and c_V and its units are given in J / g·K

Specific heat capacity of an ideal gas

We have defined specific heat capacity and molar specific heat capacity earlier in the previous chapter.

There are two specific heats of ideal gases

(i) Specific heat capacity at constant volume (C_v)

(ii) Specific heat capacity at constant pressure (C_p)

C_p and C_v are molar specific heat capacities of ideal gas at constant pressure and volume respectively for C_p and C_v of ideal gas there is a simple relation

$$C_p - C_v = R$$

where R- universal gas constant

- Since internal energy U of ideal gas depends only on temperature so subscripts P and V have no meaning

$$\rightarrow \quad CP - CV = R$$

which is the desired relation

i) System:

⇒ Anything which is under observation.
⇒ Part of universe which is under observation or study is known as system.
⇒ A **system** is a regularly interacting or interdependent group of items forming a unified whole.
⇒ Every system is delineated by its spatial and temporal boundaries, surrounded and influenced by its environment, described by its structure and purpose and expressed in its functioning.

ii) Surroundings:

⇒ Anything except system.

iv) Boundaries / walls:

⇒ Boundaries is region which separate system and surrounding.
⇒ Boundaries or walls are of two types.
⇒ **i) Diathermic:** The boundary from which heat exchange between heat and surrounding
⇒ **ii) Adiabatic:** From which no heat exchange between system and surrounding
⇒ 100 % adiabatic walls are not possible but if we use heat reflectors / insulators then the situation become approximately adiabatic. (walls of thermo-flask

i) Open system:

⇒ System which exchange both mass or matter and energy (heat).

ii) Closed system:

⇒ System which only exchange energy (heat) but not mass (matter).
⇒ Example: Boiled water in sealed container so that no evaporation produces or leave the system

iii) Isolated system:

⇒ No heat and no matter (mass) exchange between system and surroundings.
⇒ No 100 % isolated system exist.
⇒ But in general, we considered thermo-flask to be isolated
⇒ There are also some other systems;

i. **Macroscopic system:** the study of overall system, (i.e... all particles)
ii. **Microscopic system:** The study of particles of the, (i.e... specific particles)

Internal energy (GAS):

⇒ It is the energy contained within the system, excluding the kinetic energy of motion of the system as a whole and the potential energy of the system as a whole due to external force fields
⇒ The internal energy of a system can be changed by transfers of matter or heat or by doing work
⇒ According to kinetic molecular theory of gases the intermolecular forces between an ideal gas is zero. Therefore, there is no potential energy between molecules of an ideal gas. So we can say the internal energy of an ideal gas is only kinetic in nature and from this we can say that internal energy (kinetic energy) of an ideal is function of temperature only. (important)
⇒ In general practice no gas is perfectly ideal, so we can say that molecules of real gas or ideal gas exerts force of attraction on each other so there is potential and kinetic energy both, so external work is required to increase the separation of two molecules, because the potential energy associated with them increase with separation.
⇒ If volume of a gas increase increases at "**constant**" temperature then kinetic energy associated with them remains same but note that potential energy increases.

⇒ Therefore, the total internal energy of a gas depends on the volume of a gas as well as on the temperature

⇒ The kinetic energy is directly proportional to the temperature.

⇒ Therefore, we can say the net kinetic energy of a system is called temperature.

⇒ When temperature is constant kinetic energy will also be constant.

⇒ From some experiments we reach to a result that the potential energy associated with the molecules of a real gas does depend upon pressure or volume up-to some extent.

⇒ If we decrease the pressure the net attraction between molecules decreases so potential energy associated with them will also decrease, so we can conclude that this energy contributes up-to least amount of internal energy.

⇒ Internal energy for a real gas is the sum of average kinetic energy and potential energy of particles (atoms, ions and molecules) is equal to the internal energy of a system.

$$U = Kinetic\ energy + Potential\ energy$$

⇒ Internal energy for an ideal gas is the sum of average kinetic energy of a particle.

$$U = Kinetic\ energy \quad but\ Potential\ energy \neq 0$$

So, we can say that

Real gas: P.e ≠ 0, so particles will interact

Ideal gas: P.e = 0, No interaction between particles

Symbolically:

Symbolically it is represented by; "U"

⇒ **Real gas:** $U = kinetic\ energy + potential\ energy$

⇒ **Ideal gas:** $U = Kinetic\ energy$

Or

$$U = k\cdot e_{Translational} + k\cdot e_{Rotational} + k\cdot e_{Vibrational}$$

⇒ *Note that the kinetic energy translational must be present, while the rotational and vibrational may Or may not present.*

MOTION (Degree of freedom):

⇒ The number of independent ways along which particles can moves.

⇒ For a gas the degree of freedom is actually the path on axis.(x,y,z)

(a) **Translatory motion:** → Translatory degree of freedom are three (3)
Particles can move on any axis it may be x, may be y, may be z.

(b) **Rotatory motion:** → Rotatory degree of freedom is two (2)
Particles can move on any of the two axes in this case.

(c) **Vibratory motion:** → Vibratory degree of freedom is 1 (1).
Particles can move in one direction in this case

$$< k\cdot E >= \frac{3}{2}kT$$

⇒ 3 represents the translator motion

⇒ $\frac{1}{2}kT$ → energy contribution

⇒ k → Boltzman constant

Where k is equal to

$$k = \frac{R}{N_A} \quad R = Gas\ constant, \quad N_A = Avogadros\ number$$

⇒ Form above equation we know that

$$(k\cdot e)molecule \propto Temperature$$

⇒ Kinetic energy of a molecule depends only on the temperature and does not depend upon the nature.

⇒ So, we can say that the average kinetic energy of molecules is called temperature.

⇒ At low temperature only translator motion is possible.

Monoatomic molecule: these types of molecule exhibit translator motion, so having three degree of freedom.

$$(k \cdot e_{avg}) = 3\left(\frac{1}{2}kT\right)$$

$3 \rightarrow$ *represents translatory motion,* $\left(\frac{1}{2}kT\right) \rightarrow$ *energy contibution along 1 axis of one molecule*

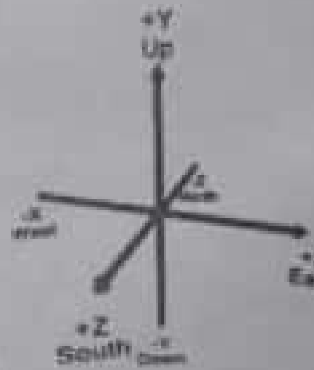
The energy contribution along all three axis that is x, y, z are given by:

$$3\left(\frac{1}{2}kT\right) = \frac{1}{2}kT + \frac{1}{2}kT + \frac{1}{2}kT$$

$$k \cdot E = \frac{3}{2}KT \rightarrow \text{Total energy contibution to a system}$$

⇒ If you are asked that what will be the energy along +ve or –ve half axis then;
We know that there are three axis (x,y,z) and these three also have negative axis on the opposite side (-x, -y,-z)
Let suppose we have x-axis for which energy = ½ K
There halfing will become = ¼ KT
SO;

$$k \cdot E = \frac{6}{4}kT = 6\left(\frac{1}{4}kT\right) \rightarrow \text{Kinetic energy along + ve or − axis}$$



- **Monoatomic** → Move only translatory → 3 = $K.E = 3/2\,KT$
- **Di atomic** → Move Translatory(3) and rotatory(2) → 5 → $K.E = 5/2\,KT$
- **Poly atomic** → Move translator (3) + Rotatory (2) + Vibratory (1) → 6 → $K.E = 6/2\,KT$

- Monoatomic means inert gases (Helium, Neon, Argon, Krypton etc)
- Diatomic means (H_2, Cl_2, O_2 etc.)
- Poly atomic means (more than two)

THEMODYNAMIC STATE VARIABLES / FUNCTIONS:

⇒ Parameters or variables which gives us information about state of system.
⇒ Or "parameters or variables which is independent of path during thermodynamic changes is known as thermodynamic states variables"
⇒ Example: Pressure (p), Volume (v), Temperature (T), Entropy (S).
⇒ Heat and work are not state functions.
⇒ Minimum state variable which explains state of a system is 2.

EQUUATION OF STATE:

⇒ Equation which relates state variables is known as equation of a state.
⇒ For example:

1. $p_1v_1 = p_2v_2$
2. $\frac{p_1}{T_1} = \frac{p_2}{T_2}$
3. $pv = nRT$

LAWS OF THERMODYNAMICS:

⇒ The laws of thermodynamics are just like Newton's law of motions.
⇒ So, these laws of thermodynamics can be treated in a wholly macroscopic way, without reference to microscopic models.
⇒ Note that thermodynamics laws were developed before the molecular theory of matter was accepted.

(i) Zeroth Law of thermodynamics:

⇒ This law states that "Two bodies or systems that are in thermal equilibrium with a third body are in equilibrium with each other".

- ⇒ The ZEROTH law is fundamental to all thermodynamics it is so named because it have a priority over the first and second law of thermodynamics, and also because it was recognized as a law only after the first and second law has been stated and assigned there name.
- ⇒ Let suppose" Two bodies A_1 and A_2 are at thermal equilibrium with each other and at same temperature, now there is one way to determine them that they are at thermal equilibrium we take some help from 3rd body which is A_3 as a thermometer (temperature sensor). If the thermometer reads the same temperature for these two bodies then these two bodies are in thermal equilibrium with each other.

(ii) First Law of thermodynamics:

- ⇒ For 1st time it shown that internal energy is a state function.
- ⇒ First of all, gives us a concept of getting mechanical work form thermodynamic system, after that engines etc. are formed.
- ⇒ For the 1st time relates mechanical work with the thermal energy.
- ⇒ This law is about law of conservation of energy.
- ⇒ Or simply if we apply law of conservation of energy to thermal system then we call it first law of thermodynamics.
- ⇒ It state that "Whenever heat is added to a system, it transforms to an equal amount of some other forms of energy".
- ⇒ Let suppose "suppose we take some gas in a system and fit piston upon it, now let suppose if we give some heat to the system, then there is possibility for the added energy to do one or both of the following two things. (i) The first one is it may increase temperature of the gas and thus increase internal energy (ΔU). (ii) while the second one is it can cause the gas to expand, thus in this way it allowing the gas to do some work on the piston(W). The amount of heat added to the system is equal to the total internal energy of system or total work done by the system, this is also the general statement of law of conservation of energy".

So

Heat added to a system = (Increase in internal energy of a system) +(External work by a system)

Or

$$Q = \Delta U + W \rightarrow *$$
$$Q = \Delta U + P\Delta V \rightarrow *$$

*Eq * represent mathematical form of first law of thermodynamics.*

- ⇒ It may be defined as "The heat energy supplied to a system is equal to increase in internal energy and the work done by the system".
- ⇒ If heat is added to a system 'Q' is positive.
- ⇒ If heat is lost by the system 'Q' is negative.
- ⇒ If work is done by the system W is positive.
- ⇒ If work is done on the system W is negative.
- ⇒ $\Delta U = Q - W$ Increase in ΔU is taken is positive while decrease is take as negative.
- ⇒ The value of both Q and W depend on the path the system is following in going from initial to final state.
- ⇒ ΔU does not depend upon the path it depends only upon the initial and final state of the system.
- ⇒ In an isolated system there is no heat flow and the work done is zero. $0 = \Delta U + 0$ or $\Delta U = 0$.
- ⇒ In a cyclic process the change in internal energy is zero. Q = 0 + W or Q = W. we can say that heat added in the cyclic process is equal to the work done during the cycle.

Application of first law of thermodynamics:

(i) Melting process:

- ⇒ When a solid change into liquid state its total internal energy increases, and this can be calculated from 1st law of thermodynamics.
- ⇒ During melting process internal energy increased by mL.

⇒ So, temperature remains constant during melting, the kinetic energy remains same, therefore for increase in internal energy potential energy is responsible.

(ii) Isobaric process:

⇒ Iso = same and bar for pressure.

⇒ A process that occur at constant pressure is called isobaric process.

⇒ It is given by:

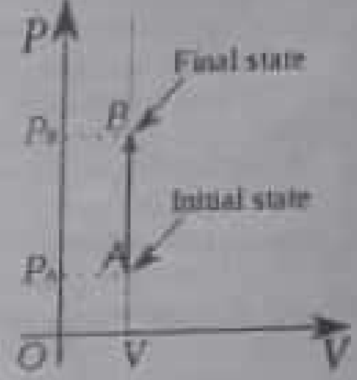
According to 1st law of thermodynamics;

$$\Delta Q = \Delta U + W$$

$$\Delta Q = \Delta U + P\Delta V$$

As pressure is constant so;

$$Q = \Delta U + W$$



⇒ In this case the heat that added increases the internal energy of a gas as well as the gas does some external works.

⇒ It is often used to covert heat into work.

⇒ One of the examples of isobaric process are boiling of water in an open container. Since the container is open the process occur at constant atmospheric pressure. At the boiling point the temperature of water no longer increases with the addition of heat. Instead there is change of phase of water from liquid to a steam.

⇒ The graph of isobaric process is called isobar.

⇒ An isobar is a straight line parallel to the volume axis.

⇒ Here Charles law is applicable.

$$v \propto T \Rightarrow \frac{v_1}{T_1} = \frac{v_2}{T_2} = \frac{v}{T} = constant$$

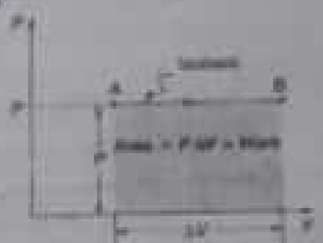
⇒ Work is the area enclosed by PV diagram.

(iii) Isochoric process:

⇒ It is a process that occur at constant volume.

⇒ In isochoric process the total work done is equal to zero.

⇒ The work done is given by; as volume is constant so; $(W = P\Delta V = P \times 0 = 0) \rightarrow Q = \Delta U$ so $(W = 0)$.



⇒ from the above equation it is clear that if heat is added to a system at constant volume then all the heat goes into increasing the internal energy of the system.

⇒ The graph of isochoric process is called isochore.

⇒ An isochore is a straight line parallel to the pressure axis.

⇒ According to 1st law of thermodynamics,

$$\Delta Q = \Delta U + P\Delta V$$

$$\Delta Q = \Delta U + 0 \text{ (at constant volume)}$$

$$\Delta Q = \Delta U$$

⇒ Charles 2nd law applicable.

$$p \propto T \rightarrow \frac{p}{T} = constant \rightarrow \frac{P_1}{P_2} = \frac{T_1}{T_2}$$

(iv) Isothermal process:

⇒ Work is area under the curve.

⇒ It is the process which takes place at constant temperature, if temperature is constant then internal energy or change in internal energy is also constant. So, U = 0

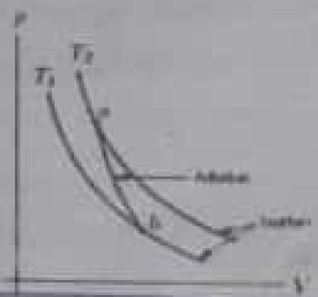
From 1st law of thermodynamics we know that;

$$\Delta Q = \Delta U + W \rightarrow *$$
$$\Delta Q = 0 + W \text{ so: } \Delta Q = W$$

⇒ *This means that heat added only do work.*
⇒ Make sure that in thermodynamic process only temperature is constant but pressure and volume changes.
⇒ Work is maximum in isothermal process
⇒ *Boyles law applicable for it;*

$$p \propto \frac{1}{v} \rightarrow p = \frac{Constant}{v} \text{ where } pv = constant$$

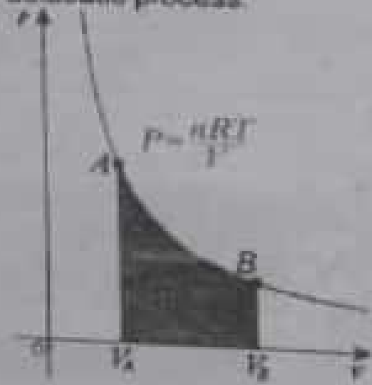
⇒ We assume the system here is an ideal gas.
⇒ The equation for isothermal processes can be derived from the equation of an ideal gas.
⇒ We know that an ideal gas of pressure p and volume v of an ideal gas is given by PV = RT.
⇒ In above equation T represent absolute temperature and R is universal gas constant.
⇒ The equation PV= constant is equation for an isothermal process.
⇒ The graph of isothermal process is called isotherm.
⇒ The isotherm is pressure and volume curve.



⇒ An isothermal expansion is: when a gas expands isothermally ΔV is positive so W and Q will also be positive.
⇒ But for isothermal compression $\Delta V = negative$ so W and Q will also be negative.
⇒ Note that during isothermal compression and expansion there is no change in internal energy of a gas.
⇒ During isothermal expansion all heat added to the system do some external work.
⇒ During isothermal compression all work done on the gas is lost as heat to the surrounding.
⇒ For isothermal expansion $V_2 < V_1$ or $P_1 > P_2$ so the work done by the gas is negative.
⇒ For isothermal compression $V_1 > V_2$ so $P_2 > P_1$ and so the work done by the gas is negative.

(V) Adiabatic process:

⇒ The process in which no heat enters or leaves the system is called adiabatic process.
⇒ In other words, no heat exchange takes place between system and surroundings.
⇒ P, V and T changes in this process.
⇒ This process can be achieved by insulating system and surrounding.
⇒ One of the examples of adiabatic processes is the rapid escape of air from a burst tyre.
⇒ The total change in heat for adiabatic processes is given by $\Delta Q = 0$.



⇒ When a gas expands adiabatically $\Delta W = positive$ so that work done by the gas is positive. And change in internal energy is given by $\Delta U = -W$. The negative sign of internal energy represent fall in temperature of system.
⇒ So, when a gas expands adiabatically it losses internal energy equal to work done by the gas and so the temperature of the gas falls.
⇒ In other hand when gas compressed adiabatically $\Delta W = negative$ so the work done by the gas is negative, while the internal energy is +ve.
⇒ The change in internal energy is case of adiabatic compression is given by $\Delta U = -(-W) = +W$.
⇒ The positive sign with the internal energy shows that positive change occur in internal energy (it increases) so in this way temperature also rises.

⇒ Adiabatic processes are not isothermal.
⇒ 100% adiabatic process is not possible, but some processes are approximately adiabatic process like, production of sound waves (longitudinal waves), tire burst or balloon burst.
⇒ All those processes which occur quickly are approximately adiabatic.
⇒ Boyles law applicable but here we add gamma factor.

$$p \propto \frac{1}{v^{\gamma}} \rightarrow pv^{\gamma} = constant \text{ where } \gamma = \frac{C_p}{C_v} \text{ and } \gamma = gamma\ factor$$

Difference between isothermal and adiabatic process:

S/NO	ISOTHERMAL PROCESS	ADIABATIC PROCESS
1	Temperature remains constant $\Delta T = 0$.	No heat is added or removed; $Q = 0$
2	The changes occur slowly.	The changes occur suddenly.
3	The system is thermally conducting to the surrounding.	The system is thermally insulated from surrounding.
4	No changes occur in the internal energy of a system.	Changes in internal energy occur.
5	Equation of this process is PV = constant	Equation of this process is PV^{γ} = constant
6	Specific heat becomes infinite.	Specific heat becomes zero.
7	At any point on isothermal curve the slope is less than the slope of adiabatic curve at that point.	At any point on the adiabatic curve the slope is more that the slope of isothermal curve at that point.

Summary:

S. NO	process	Law applicable	Quantity remains constant	ΔU	ΔW	$\Delta H = \Delta U + \Delta W$
1	*Isochoric (iso metric or iso volumetric)*	*Gay Lussac's Law*	*Volume*	$nC_v dT$	0	$nC_v dT$
2	*Isobaric*	*Charle's Law*	*Pressure*	$nC_v Dt$	$P(V_2 - V_1)$	$nC_p dT$
3	*Isothermal*	*Boyle's law*	*Temperature*	0	$nRT \ln\frac{V2}{V1}$	$nRT \ln\frac{V2}{V1}$
4	*Adiabatic*	–	pv^{γ} = constant	$-\Delta W$	$\frac{P_1V_1 - P_2V_2}{(n-1)}$	0

- **Isenthalpic process:** occurs at a constant enthalpy
- **Isentropic process:** a reversible adiabatic process, occurs at a constant entropy
- **Steady state process:** occurs without a change in the internal energy

Signs of Q and W for a system	
$Q > 0$	*Energy added to system as heat*
$Q < 0$	*Energy removed from system as heat*
$Q = 0$	*No transfer of energy as a heat*
$W > 0$	*Work done by system (expansion of gas)*
$W < 0$	*Work done on system (compression of system)*
$W = 0$	*No work done*

Limitations of First (1st) Law of Thermodynamics:

- The first law does not indicate the direction of transfer of heat. All we know that heat always flow from a region of higher concentration to a region of lower concentration (i.e. from hot body to cold body) now if we considered a case that if the heat has to leave the cold body which does not occur in fact. Energy would still be conserved which is not explained by 1st law.
- It does not tell us about that in which condition heat can be converted into work.
- It does not tell us that why the whole of heat energy cannot be converted into mechanical work continuously.
- Also, there are more many processes that occur in nature but their reverse cannot in such cases the 1st law is violated if there reverse takes place. To explain lack of reversibility scientists makes a new principle called 2nd law of thermodynamics.

Reversible and Irreversible processes:

⇒ Reversible processes are any process which can be made to proceed in the reverse direction so that it passes through exactly the same states in all respects as in the direct process is called reversible process.

⇒ Irreversible process is any process that cannot proceed in reverse direction is called irreversible process.

⇒ Irreversible processes are uni-directional while reversible proceed in both directions.

⇒ In a reversible process the system is nearly at equilibrium all the time.

⇒ Reversible process is ideal.

⇒ Any process will be reversible if it strictly obeys the following conditions.

(i) The process should take place at extremely slow rate.

(ii) The system should be free from dissipative forces like friction force and any other agent which loss energy of a system.

⇒ In everyday life no 100% reversible process is possible.

⇒ All mechanical process takes place under the action of conservative forces are reversible process.

⇒ In irreversible processes a part of the energy of the system is lost and cannot be recovered back.

⇒ **All natural processes are irreversible.**

⇒ ***Irreversible processes are;***

(i) Rusting of iron

(ii) The decay of organic matter

(iii) Dissolving of sugar or salt in water

(ii) 2nd Law of thermodynamics:

⇒ ***Clausius statement (Reverse heat engine):*** It can be stated as "Heat flows naturally from a hot body to a cold body; heat will never itself flow form a cold body to hot body".

⇒ It is also the statement of "**Law of conservation of energy**".

⇒ ***Kelvin statement (Heat engine):*** It is impossible for an engine in a cyclic process to extract heat from a reservoir and convert it completely into work *i.e.,* a perfect heat engine can never be constructed. The internal energy converted to useful work in heat engines flow from a hot region to a cold region. Every heat engine will absorb energy from a reservoir of higher temperature and convert some of this energy into mechanical work and discard the remaining energy to some lower temperature reservoir usually which is called sink. This can be observed in gasoline engine.

⇒ The second law of thermodynamics tells us that no heat engines can convert all heat energy into a mechanical work.

⇒ So, some heat is always wasted in processes.

⇒ These two statements one of Clausius and other of kelvin are equivalent.

- ⇒ We can also explain this law on the basis of entropy.
- ⇒ Entropy is measure of disorder of a system.
- ⇒ When entropy of a system increases there is decrease in the energy available to do useful work.
- ⇒ Statement of second law in terms of entropy is 'In any natural (irreversible) processes the entropy increases i.e. some energy may available to do useful work.
- ⇒ Entropy tell us that how much energy or heat is unavailable for conversion into useful work.
- ⇒ The second law tells us equivalence of heat and works.
- ⇒ It is concerned with the conversion of heat into work which in many cases done by engine.

Heat Engine:

- ⇒ We can easily produce thermal energy by doing work or we can produce thermal energy from mechanical energy. Also, this conversion can be 100%.
- ⇒ But the opposite process of above which is continuous conversion of heat into work can never be 100% efficient.
- ⇒ A device which heat into mechanical work is called engine.
- ⇒ The engine must work in a cycle.
- ⇒ All heat engines operate by taking some working substance around a cycle.
- ⇒ Every heat engine will
  (a) absorb heat from a reservoir of higher temperature,
  (b) convert some of this heat energy into a mechanical work and
  (c) transfer the remaining heat energy into sink or in other word which is called low temperature reservoir.
- ⇒ A simple heat engine consists of a cylinder containing a gas.
- ⇒ The net work done by gas in any close cycle is equal to area enclosed by closed loop in the PV diagram.
- ⇒ From the first law net work done in a cycle = heat gained by a gas = $Q_H - Q_L$

  Net work done by the gas in a cycle

$$W = Q_H - Q_L$$

Q_H = heat taken in at high temperature

Q_L = heat rejected at lower temperature

- ⇒ The efficiency of heat engine is 'the ratio of the work (W) it does to the heat input Q_H at the higher temperature

$$\eta = \frac{\text{work done}}{\text{Energy supplied}} = \frac{W}{Q_H}$$

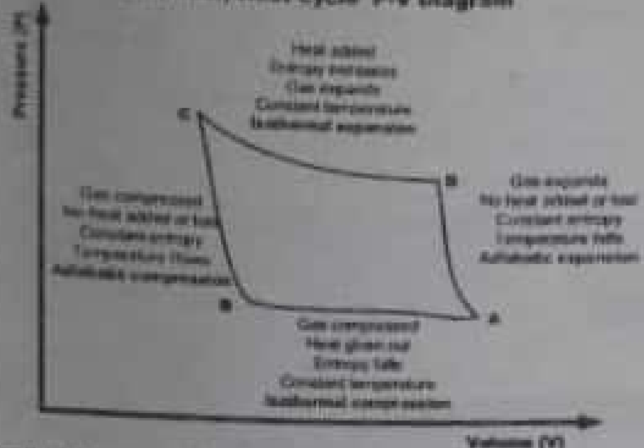
as shown $w = Q_H - Q_L$

$$\eta = \frac{Q_H - Q_L}{Q_H} \Rightarrow \eta = 1 - \frac{Q_L}{Q_H}$$

- ⇒ The above equation says that the efficiency of a heat engine will be greater if Q_L is made small.
- ⇒ But in common observation it is impossible to reduce Q_L to zero. It means that heat engine can never be 100 % efficient.

CARNOT CYCLE OR ENGINE:

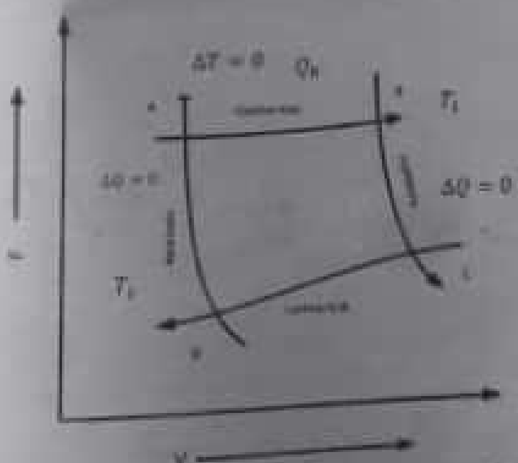
Carnot (Ideal) Heat cycle P-V Diagram



- ⇒ It was first theoretically discussed by SADI CARNOT in 1824.
- ⇒ Carnot recognized that work can be done only when heat flow from a region o higher concentration to a region of lower concentration.
- ⇒ Carnot proposed an ideal engine that operates cyclically and reversibly between two temperatures.
- ⇒ Carnot says that his proposed cycle or engine is the more efficient cycle or engine possible.
- ⇒ A Carnot cycle consist of two adiabatic and two isothermal process all of which are reversible.
- ⇒ Carnot's engine works between two temperatures

$$T_1 - \textit{temperature of hot reservoir}$$
$$T_2 - \textit{temperature of cold reservoir}$$

- ⇒ In a Complete Carnot's Cycle system is taken from temperature T_1 to T_2 and then back from temperature T_2 to T_1
- ⇒ We have taken ideal gas as the working substance of Carnot engine.
  - ⇒ Fig below is an indicator diagram for Carnot Cycle of an ideal gas



(i) In step $b \rightarrow c$ iso-thermal expansion of gas taken place and thermodynamic variables of gas changes from (P_1, V_1, T_1) to (P_2, V_2, T_1)

⇒ If Q_1 is the amount of heat absorbed by working substance from the source and W_1 the work done by the gas then from equation

$$Q_1 = W_1 = nRT_1 \ln\left[\frac{V_2}{V_1}\right] \quad (1)$$

as process is iso-thermal.

(ii) Step b → c is an adiabatic expansion of gas from (P_2, V_2, T_1) to (P_3, V_3, T_2). Work done by gas in adiabatic expansion is given by equation

$$W_2 = \frac{nR(T_1 - T_2)}{\gamma - 1} \quad (2)$$

(iii) Step c → d is iso-thermal compression of gas from (P_3, V_3, T_2) to (P_4, V_4, T_2). Heat Q_2 would be released by the gas to the at temperature T_2

⇒ Work done on the gas by the environment is

$$W_3 = Q_2 = nRT_2 \ln\left(\frac{V_3}{V_4}\right) \quad (3)$$

(iv) Step d → a is adiabatic compression of gas from (P_4, V_4, T_2) to (P_1, V_1, T_1)

⇒ **Work done on the gas is**

$$W_4 = \frac{nR(T_1 - T_2)}{\gamma - 1} \quad (4)$$

⇒ **Now total work done in one complete cycle is**

$$W = W_1 + W_2 - W_3 - W_4$$
$$= nRT_1 \ln\left(\frac{V_2}{V_1}\right) - nRT_2 \ln\left(\frac{V_3}{V_4}\right) \quad (5)$$

as $W_2 = W_4$

⇒ **Efficiency of Carnot engine**

$$\eta = \frac{W}{Q_1} = 1 - \left(\frac{Q_2}{Q_1}\right) = 1 - \frac{\left(\frac{T_2}{T_1}\right) \ln\left(\frac{V_3}{V_4}\right)}{\ln\left(\frac{V_2}{V_1}\right)} \quad (6)$$

$$\text{or} \quad \eta = 1 - \frac{T_2 \ln\left(\frac{V_3}{V_4}\right)}{T_1 \ln\left(\frac{V_2}{V_1}\right)} \quad (7)$$

Since points b and c lie on same iso thermal

$$\Rightarrow P_1V_1 = P_2V_2 \quad (8)$$

also points c and d lie on same adiabatic

$$\Rightarrow P_2(V_2)^\gamma = P_3(V_3)^\gamma \quad (9)$$

also points d and a lie on same iso thermal and points a and b on sum adiabatic thus,

$$P_3V_3 = P_4V_4 \quad (10)$$
$$P_4(V_4)^\gamma = P_1(V_1)^\gamma \quad (11)$$

multiplying all the above four equation me get

$$\frac{V_3}{4} = \frac{V_2}{V_1} \quad (12)$$

Putting this in equation (7) we get

$$\eta = 1 - \left(\frac{T_2}{T_1}\right) \quad (13)$$

is Carnot Heat engine

⇒ Equation 13 gives us efficiency of a Carnot heat engine. T_1 and T_2 are absolute temperature From above equation we can draw following conclusions that efficiency of Carnot engine is:

(i) It tells us that efficiency of a CARNOT cycle depend only on the highest and lowest temperature of the working fluid.

(ii) In practical life the low temperature is usually ambient temperature.

(iii) To maximize effect, we must use high temperature.

MCQS POINTS:

⇒ If $T_1 = T_2$ then efficiency is equal to zero. It is clear that efficiency will be 100% if low temperature = 0 kelvin. this is also a result of second law of thermodynamics.

⇒ All reversible engines operating in cycles between the same temperature T_1 (high) and T_2 (Low) have the same efficiency (regardless of the working substances.) Not depend.

⇒ The efficiency of an engine is increases by decreasing T_2/T_1.
⇒ The efficiency of a real heat engine is less than that given by the above efficiency equations it is because of losses due to frictional effects.
⇒ Note that whenever the ratios of temperature are involved the absolute temperature must be used.
⇒ $\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1} \rightarrow \frac{Q_2}{Q_1} = \frac{T_2}{T_1}$

Carnot Theorem

⇒ Carnot Engine is a reversible engine
⇒ Carnot's theorem consists of two parts
(i) no engine working between two given temperatures can be more efficient than a reversible Carnot engine working between same source and sink.
(ii) all reversible engines working between same source and sink (same limits or temperature) have the same efficiency irrespective the working substance.
⇒ For any non-CARNOT reversible engine $\eta < 1 - \frac{T_2}{T_1}$

Extra information:

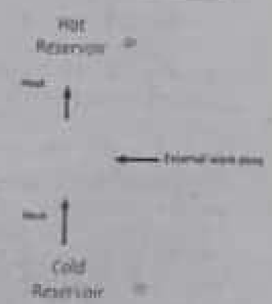
(i) There are two main classes (types) of heat engines.
(ii) One are external combustion engines, which are the type of engines in which the working substance such as steam are produce by burning the fuel outside the cylinder. Steam engine is external combustion engine. Efficiency of a common steam engines ranges from 12% to 16%.
(iii) The other one is internal combustion engine, which are the types of engines in the fuel burnt inside the cylinder such as petrol engine and diesel engines, i.e efficiency of these engines → petrol engine is 25% while that of diesel engine is 40%.

Interesting: Don't Shop for a Carnot Engine

The Carnot engine is only an idealization. If a Carnot engine were developed in an effort to maximize efficiency, it would have zero power output because for all of the processes to be reversible, the engine would have to run infinitely slowly.

Refrigerator

⇒ Refrigerators works in reverse direction of heat engines.
⇒ In refrigerators working substance extracts heat Q_2 from sink at lower temperature T_2
⇒ Some external work is performed by the compressor of refrigerator and then heat Q_1 is rejected the source, to the radiator of the refrigerator.



Co-efficient of performance:

⇒ The effectiveness of refrigerator is measured by its coefficient of performance. It is defined as the ratio of heat extracted per cycle at low temperature to the work input required.

$$\beta = \frac{\text{Amount of heat absorbed from the cold reservoir}}{\text{work done in running the machinery}}$$

$Q2$ – heat absorbed from cold reservoir.
$Q1$ – heat rejected to hot reservoir during one complete cycle
$W = (Q1 - Q2)$ is the work done in running the machinery

$$\beta = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2} \quad (1)$$

- ⇒ Like heat engines refrigerators cannot work without some external work done on the system Hence coefficient of performance cannot be infinite
- ⇒ The smaller is the temperature difference the greater will be coefficient of performance, this make sense because it takes less work to force heat flow to reservoir that is at slightly higher temperature than to one at much higher temperature
- ⇒ The COP indicates the efficiency of refrigerator. The greater COP greater will be efficiency



A refrigerator does work (b) in order to transfer energy as heat from the inside of the refrigerator (c) to the air outside the refrigerator (a).

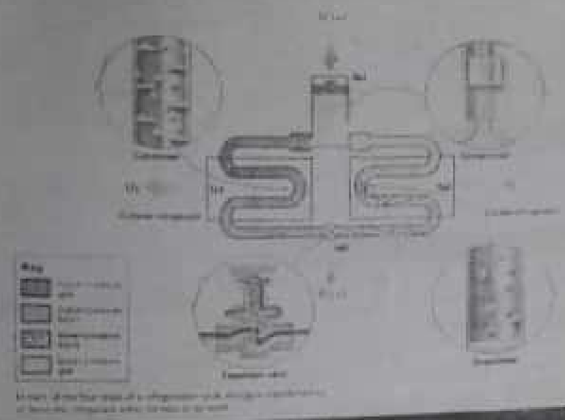
For your information:
THE INSIDE STORY ON REFRIGERATORS

As shown in the photograph below, a refrigerator can be represented schematically as a system that transfers energy from a body at a low temperature **(c)** to one at a high temperature **(a).** The refrigerator uses work performed by an electric motor to compress the *refrigerant*, which is a substance that evaporates at a very low temperature. In the past, ammonia was used as a refrigerant in home refrigerators. However, ammonia leaks pose a risk because pure ammonia is highly toxic to people. In the 1930s, home refrigerators began using a newly developed, nontoxic class of refrigerants called *CFCs (chlorofluorocarbons)*. Today, it is known that CFCs damage the ozone layer. Since the 1990s, home refrigerators have used refrigerants that are less harmful to the ozone layer. The process by which a refrigerator operates consists of four basic steps, as illustrated in the diagram on the next page. The system to and from which energy is transferred is defined here as the refrigerant contained within the inner surface of the tubing. Initially, the liquid refrigerant is at a low temperature and pressure so that it is colder than the air inside the refrigerator. The refrigerant absorbs energy from inside the refrigerator and lowers the refrigerator's interior temperature. This transfer of energy as heat increases the temperature of the liquid refrigerant until it begins to boil, as shown in **(a).** The refrigerant continues to absorb energy until it has completely vaporized. Once it is in the vapor phase, the refrigerant is passed through a *compressor*. The compressor does work on the gas by decreasing its volume without transferring energy as heat, as shown in **(b).** This adiabatic process increases the pressure and internal energy (and thus the temperature) of the gaseous refrigerant. In the next step, the refrigerant is moved to the outer parts of the refrigerator, where thermal contact is made with the air in the room. The refrigerant gives up energy to the environment which is at a lower temperature, as shown in **(c).** The gaseous refrigerant at high pressure then condenses at a constant temperature to a liquid. The liquefied refrigerant is then brought back into the refrigerator. Just outside the low-temperature interior of the refrigerator, the refrigerant goes through an *expansion valve* and expands without absorbing energy as heat. The liquid then does work as it moves from a high-pressure region to a low-pressure region, and its volume increases, as shown in **(d).**



<u>NOTE:</u> Entropy decreases in many systems on Earth. For example, atoms and molecules become incorporated into complex and orderly biological structures such as cells and tissues. These appear to be spontaneous because we think of the Earth itself as a closed

system. So much energy comes from the sun that the disorder in chemical and biological systems is reduced, while the total entropy of the Earth, sun, and intervening space increases.



ENTROPY:

⇒ The distortedness of a system is called entropy.

⇒ It may be stated that the unavailability of useful energy.

⇒ Symbolically it is represented is "S".

⇒ **MATHEMATICALLY:**

$$S = \frac{\Delta Q}{\Delta T} \Rightarrow S = \frac{Q}{T}$$

⇒ **UNIT:**

$$^{J}/_{K}$$

1. If we put sheet on an iron particle.
2. After that we take another sheet on which we place copper particles.
3. And we take another sheet on which we place aluminum particles.

⇒ If these sheets are removed these all particles will be mixed up and disorder-ness of a system will be created.

⇒ Zero order entropy is arbitrary we can choose zero order entropy at any temperature like zero potential energy.

⇒ If a temperature of the system become maximum constant (boiling point/temperature) with this the entropy of a system will be also maximum constant.

$$Temperature\ (T) = maximum\ constant$$
$$S = maximum\ constant$$
$$if\ \Delta T = 0\ \ then\ \ \Delta S = 0$$

⇒ **For "REVERSIBLE PROCESS":**

$$Energy\ lost = 0$$
$$S_{system} = constant$$
$$S_{surrounding} = constant$$

So:

$$\Delta S_{sys} = 0, \quad and \quad \Delta S_{sur} = 0$$

$$SYSTEM + SURROUNDING = UNIVERSE$$

So:

$$S_{universe} = constant$$

$$\Delta S_{universe} = 0$$

⇒ **For "IRREVERSIBLE PROCESS":**

$$Heat\ lost \neq 0$$

$$\Delta S system > 0 \quad and \quad \Delta S_{surrounding} > 0$$

So;

$$S_{sys} \neq constant \quad and \quad S_{sur} \neq constant$$

Then entropy of the both system and surroundings will be increases so;

$$\Delta S_{universe} > 0$$

⇒ **For "ALL-NATURAL PROCESSES":**

$$\Delta S_{sys} + \Delta S_{sur} \geq 0$$

or

$$\Delta S_{uni} \geq 0$$

⇒ **If all processes are continued a stage will be reached:**

$$S_{universe} = \max(constant)$$

$$\Delta S_{uni} = 0$$

Then total temperature of universe;

$$T_{universe} = max.constant$$

At this stage heat flow will be stopped and **heat death of universe** will be occurred

⇒ If same amount of heat is transferred in cold and hot system then entropy change will be maximum in cold system.

⇒ Note that Carnot engine is reversible heat engine, so the points we explain here for reversible processes can be also applied for Carnot heat engine

Formula Sheet

S/N	QUANTITY	EQUATION
1)	Internal energy	$U = K.E_{trans} + K.E_{Rot} + K.E_{vib}$
2)	Thermodynamic work	$W = P\Delta V$
3)	Equation of state because it relate state variable	$P_1V_1 = P_2V_2$ $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ $PV = nRt$
4)	1st Law of thermodynamics	$\Delta Q = \Delta U + \Delta W$ $\Delta Q = \Delta U + P\Delta V$
5)	Isothermal process	$\Delta Q = W$ $PV = constant$
6)	Isobaric process	$\Delta Q = \Delta U + W$ $\frac{V}{T} = constant$
7)	Isochoric process	$W = 0$ $\Delta Q = \Delta U$
8)	Adiabatic process	$\Delta Q = 0$ $0 = \Delta U + W$
9)	Molar specific Heat constant	$\Delta Q = C_N \Delta T$ C = Specific heat constant
10)	Mass specific heat constant	$\Delta Q = C_{mass}\Delta T$
11)	Specific heat at constant pressure	$\Delta Q_p = nC_p\Delta T$
12)	Specific heat at constant volume	$\Delta Q_v = nC_v\Delta T$
13)	Heat engine	Efficiency: $\eta = \frac{output}{Input} \Rightarrow \frac{W}{Q_{High}}$ $\eta = \frac{Q_{High} - Q_{Low}}{Q_{High}}$ $\eta = 1 - \frac{Q_{Low}}{Q_{High}} \Rightarrow 1 - \frac{T_{Low}}{T_{High}}$ Q_{Hi} = heat of Hugh temp reservoir Q_{Low} = heat of low temp reservoir
14)	Carnot theorem	$\eta = \frac{T_H - T_L}{T_H} = \frac{\Delta T}{T_H}$ $\eta = 1 - \frac{T_L}{T_H}$
15)	Reverse heat engine	$P_c = \frac{Q_{low}}{Q_H - Q_l}$ P_c = Performance of cooling effect
16)	Heat pump	$P_H = \frac{Q_H}{Q_H - Q_L} = \frac{T_H}{T_H - T_L}$
17)	Entropy	$S = \frac{\Delta Q}{\Delta T} \rightarrow S = \frac{Q}{T}$

Some Important Points and Tricks:

1) Thermodynamics is based on two important laws, 1st and 2nd law of thermodynamics
2) The relationship between kinetic energy and pressure is;

Let say "if the kinetic energy of the gas molecules is tripled then pressure exerted by the gas on the walls of the container" will be———?(Triple)

$$P = \frac{2}{3}\frac{N}{V}\frac{1}{2}mv^2$$

$$if\ \frac{2N}{3V} = constant\ the,$$

$$P \propto kinetic\ energy$$

the pressure exerted by a gas on the walls of the container id directly proportional to the K.E of a gas molecule

3) The value of universal gas constant "R" is 8.314 J mol⁻¹ k⁻¹
4) The relationship between pressure and temperature is;

Let say "if the absolute temperature "T" is doubled, then average translational kinetic energy will become——?(double)
From CHARLE'S law" the pressure is directly proportional to the absolute temperature "T" of the gas provided if volume is kept constant;

$$P \propto T$$

5) The ratio of R/N$_A$ which plays the role of gas constant per molecule is called Boltzmann's constant
6) The Boltzmian's constant have a value of 1.83 x 10⁻²² J/K
7) For "N" molecules of gas of total mss 'm' or 'n' moles the total kinetic energy is given by $\frac{3}{2}nRT$
8) The relationship between absolute temperature and volume of the gas is;

Let say "if absolute temperature of the gas is tripled keeping the pressure constant the volume of the gas become——? (triple)
From CHARLE'S LAW: the volume is directly proportional to absolute temperature "T" of the gas provided pressure is kept constant

$$Volume \propto Temperature$$

9) The equation for general gas law is given by "PV=nRT".
10) The average speed of any molecule "let say here we take oxygen molecule" in air under standard condition of temperature and pressure is______?

The average kinetic energy per molecule of a gas is related to the absolute temperature of the gas by the relation;

$$\frac{1}{2}mv^2 = \frac{3}{2}kT$$

$$v^2 = \frac{3kT}{m} \Rightarrow \frac{3N_AkT}{N_Am} = \frac{3RT}{M}$$

$$At\ S.T.P = 0^0C = 273k$$

$$R = 8.314Jmol^{-1}k^{-1}$$

$$molecular\ mass\ of\ molecule\ (here\ oxygen)$$

$$= O_2 \Rightarrow M = 32gmol^{-1}$$

$$= 0.032kgmol^{-1}$$

$$v = \frac{3(8\cdot314)(273)}{0.032} \Rightarrow 461.3m/s$$

11) The pressure exerted by "N" molecules of an ideal gas contained in the volume "V" is——?

As;

$$P = \frac{1}{3}\frac{N}{V}m_1v^2 \rightarrow (i)$$

But Nm$_1$ = m, the mass of the gas and density ρ is mass per unit volume;

$$\rho = \frac{Nm_1}{V} = \frac{m}{V}$$

$substituting\ \frac{Nm_1}{V}\ by\ \rho\ in\ equation\ (i) we\ get;$

$$P = \frac{1}{3}\rho v^2$$

12) The first law of thermodynamics is a relationship between there forms of energy, work, heat and internal energy.
13) In thermodynamics work is said to be done by the system when system expands (in isobaric process when the system expands the work is done.
14) The work done by a system is taken positive and the work done on the system is considered as negative.
15) The energy added to a system is such a way that a difference of temperature is not directly involved is known as work done
16) Mathematically 1st law of thermodynamics is $\Delta Q = \Delta V + \Delta W$ when

heat enters a system then ΔQ is taken as positive.

17) If heat is imparted to the gas and the volume of the system remains constant then work done is equal to;

$$\Delta W = force \times displacement$$

If volume of the system is constant then the displacement is zero and so is the work done

18) In isochoric process the entire amount of heat supplied to the gas is converted to the internal energy.

It is because " in isochoric process when heat ΔQ is imparted to the system, the system neither expands nor contracts work is neither done by the system nor on system the work done is;

$$\Delta W = 0$$

$$as\ \Delta Q = \Delta U + \Delta W$$

$$\Delta Q = \Delta U + 0$$

$$\Delta Q = \Delta U$$

This means that in isochoric process the entire amount of the heat supplied to the gas is converted to the internal energy of the gas

19) When heat is added to the system is entirely converted into the internal energy of the system then pressure and temperature of the system both will increase.

20) When the system contracts then the work is done on the system which is taken as negative.

21) In isobaric processes the heat supplied is converted into the work, let see, Isobaric expansion of a system often used to convert heat into work;

$$Workdone = P\Delta V$$

where "P" is the pressure and ΔV is the change in volume of the system.

for isobaric processes we have;

$$\Delta Q = \Delta U + \Delta W$$

$$\Delta Q = \Delta U + P\Delta V$$

22) We know that "the internal energy of a system depends on the temperature of the system

In isothermal process, $\Delta U = 0$, therefore, $\Delta T = 0$

It means in isothermal process temperature remains constant.

23) The amount of heat required to raise the temperature of one mole of a gas by 1K while keeping its volume constant is called "constant volume molar specific heat Cv"

24) The amount of heat required to raise the temperature of one mole of a gas by 1K while keeping its pressure constant is called "constant pressure molar specific heat Cp"

25) The graphic representation of an adiabatic expansion of an ideal gas is known as "hyperbola"

26) The amount of heat absorbed by a body is proportional to its area

$$Q = mc\Delta T$$

27) The specific heat of mono-atomic gases will be smaller then those of polyatomic gases because in a mono atomic gases whole of the heat supplied is used up in increasing the translator kinetic energy i.e. temperature. Wheras in a diatomic or polyatomic gas a part of energy supplied is wasted in incresing the rotational kinetic energy.

28) If m is mass of the body and "c" is its heat capacity then heat capacity of the body is given by;

$$Q = mc$$

MULTIPLE CHOICE QUESTIONS

1) The internal energy of an ideal gas depends upon
(a) Specific volume (b) Pressure
(c) Temperature (d) Density

2) In changing the state of thermodynamics from A to B state, the heat required is Q and the work done by the system is W. The change in its internal energy is
(a) Q + W (b) Q – W (c) Q (d) [illegible]

3) Heat given to a system is 35 joules and work done by the system is 15 joules. The change in the internal energy of the system will be
(a) – 50 J (b) 20 J (c) 30 J (d) 50 J

4) The temperature of an ideal gas is kept constant as it expands. The gas does

external work. During this process, the internal energy of the gas
(a) Decreases (b) Increases
(c) Remains constant
(d) Depends on the molecular motion

5) The first law of thermodynamics is concerned with the conservation of
(a) Momentum (b) Energy (c) Mass (d) Temperature

6) If the amount of heat given to a system be 35 joules and the amount of work done by the system be 15 joules, then the change in the internal energy of the system is
(a) - 50 joules (b) 20 joules (c) 30 joules (d) 50 joules

7) A system is given 300 calories of heat and it does 600 joules of work. How much does the internal energy of the system change in this process (J = 4.18 joules/cal)
(a) 654 Joule (b) 156.5 Joule (c) – 300 Joule (d) – 528.2 Joule

8) Work done on or by a gas, in general depends upon the
(a) Initial state only
(b) Final state only
(c) Both initial and final states only
(d) Initial state, final state and the path

9) Find the change in internal energy of the system when a system absorbs 2 kilocalorie of heat and at the same time does 500 joule of work
(a) 7900 J (b) 2200 J (c) 5600 J (d) 6400 J

10) A system performs work ΔW when an amount of heat is ΔQ added to the system, the corresponding change in the internal energy is ΔU. A unique function of the initial and final states (irrespective of the mode of change) is
(a) ΔQ (b) ΔW (c) ΔU and ΔQ (d) ΔU

11) 110 J of heat is added to a gaseous system, whose internal energy change is 40 J, then the amount of external work done is
(a) 150 J (b) 70 J (c) 110 J (d) 40 J

12) Which of the following is not thermodynamical function
(a) Enthalpy (b) Work done (c) Gibb's energy (d) Internal energy

13) When the amount of work done is 333 cal and change in internal energy is 167 cal, then the heat supplied is
(a) 166 cal (b) 333 cal (c) 500 cal (d) 400 cal

14) First law thermodynamics states that
(a) System can do work
(b) System has temperature
(c) System has pressure
(d) Heat is a form of energy

15) A thermo-dynamical system is changed from state (P_1,V_1) to (P_2,V_2) by two different process. The quantity which will remain same will be
(a) Δ Q (b) ΔW (c) ΔQ + ΔW (d) ΔQ - ΔW

16) In thermodynamic process, 200 Joules of heat is given to a gas and 100 Joules of work is also done on it. The change in internal energy of the gas is
(a) 100 J (b) 300 J (c) 419 J (d) 24 J

17) A perfect gas contained in a cylinder is kept in vacuum. If the cylinder suddenly bursts, then the temperature of the gas
(a) Remains constant (b) Becomes zero
(c) Increases (d) Decreases

18) If and represent the heat supplied to the system and the work done on the system respectively, then the first law of ΔQ ΔW thermodynamics can be written as
(a) $\Delta Q = \Delta U + \Delta W$ (b) $\Delta Q = \Delta U - \Delta W$ (c) $\Delta Q = \Delta W - \Delta U$ (d) $\Delta Q = -\Delta W - \Delta U$
Where ΔU is the internal energy

19) For free expansion of the gas which of the following is true
(a) Q = W = 0 and Δ Eint = 0
(b) Q = 0,W > 0 and ΔEint = -W
(c) W = 0,Q > 0, and Δ Eint = Q
(d) W > 0,Q < 0 and ΔEint = 0

20) Which of the following can not determine the state of a thermodynamic system
(a) Pressure and volume
(b) Volume and temperature
(c) Temperature and pressure
(d) Any one of pressure, volume or temperature

21) In a given process for an ideal gas, dW = 0 and dQ < 0. Then for the gas
(a) The temperature will decrease
(b) The volume will increase
(c) The pressure will remain constant

(d) The temperature will increase

22) Which of the following parameters does not characterize the thermodynamic state of matter
(a) Volume (b) Temperature (c) Pressure (d) Work

23) In a thermodynamic system working substance is ideal gas, its internal energy is in the form of
(a) Kinetic energy only
(b) Kinetic and potential energy
(c) Potential energy
(d) None of these

24) Which of the following statements is correct for any thermodynamic system
(a) The internal energy changes in all processes
(b) Internal energy and entropy are state functions
(c) The change in entropy can never be zero
(d) The work done in an adiabatic process is always zero

25) In a thermodynamic process, pressure of a fixed mass of a gas is changed in such a manner that the gas molecules gives out 20 J of heat and 10 J of work is done on the gas. If the initial internal energy of the gas was 40 J, then the final internal energy will be
(a) 30 J (b) 20 J (c) 60 J (d) 40 J

26) Heat is not being exchanged in a body. If its internal energy is increased, then
(a) Its temperature will increase
(b) Its temperature will decrease
(c) Its temperature will remain constant
(d) None of these

27) First law of thermodynamics is a special case of
(a) Newton's law
(b) Law of conservation of energy
(c) Charles's law
(d) Law of heat exchange

28) Out of the following which quantity does not depend on path
(a) Temperature (b) Energy (c) Work (d) None of these

29) Temperature is a measurement of coldness or hotness of an object. This definition is based on
(a) Zeroth law of thermodynamics
(b) First law of thermodynamics
(c) Second law of thermodynamics
(d) Newton's law of cooling

30) The state of a thermodynamic system is represented by
(a) Pressure only (b) Volume only
(c) Pressure, volume and temperature
(d) Number of moles

31) If a system undergoes contraction of volume then the work done by the system will be
(a) Zero (b) Negligible
(c) Negative (d) Positive

32) Which of the following is incorrect regarding the first law of thermodynamics
(a) It introduces the concept of the internal energy
(b) It introduces the concept of the entropy
(c) It is not applicable to any cyclic process
(d) None of the above

33) For an ideal gas, in an isothermal process
(a) Heat content remains constant
(b) Heat content and temperature remain constant
(c) Temperature remains constant
(d) None of the above

34) Can two isothermal curves cut each other
(a) Never (b) Yes
(c) They will cut when temperature is 0°C
(d) Yes, when the pressure is critical pressure

35) In an isothermal expansion
(a) Internal energy of the gas increases
(b) Internal energy of the gas decreases
(c) Internal energy remains unchanged
(d) Average kinetic energy of gas molecule decreases

36) A vessel containing 5 litres of a gas at 0.8 m pressure is connected to an evacuated vessel of volume 3 litres. Th resultant pressure inside will be (assuming whole system to be isolated
(a) 4/3 m (b) 0.5 m (c) 2.0 m (d) 3/4 m

37) The gas law $\frac{PV}{T} = constant$ is true for?
(a) Isothermal changes only
(b) Adiabatic changes only
(c) Both isothermal and adiabatic

changes
(d) Neither isothermal nor adiabatic changes

38) If a gas is heated at constant pressure, its isothermal compressibility
(a) Remains constant
(b) Increases linearly with temperature
(c) Decreases linearly with temperature
(d) Decreases inversely with temperature

39) An ideal gas A and a real gas B have their volumes increased from V to 2 V under isothermal conditions. The increase in internal energy
(a) Will be same in both A and B
(b) Will be zero in both the gases
(c) Of B will be more than that of A
(d) Of A will be more than that of B

40) A thermally insulated container is divided into two parts by a screen. In one part the pressure and temperature are P and T for an ideal gas filled. In the second part it is vacuum. If now a small hole is created in the screen, then the temperature of the gas will
(a) Decrease (b) Increase
(c) Remain same (d) None

41) A container that suits the occurrence of an isothermal process should be made of
(a) Copper (b) Glass
(c) Wood (d) Cloth

42) A thermodynamic process in which temperature T of the system remains constant though other variable P and V may change, is called
(a) Isochoric process
(b) Isothermal process
(c) Isobaric process (d) None of these

43) If an ideal gas is compressed isothermally then
(a) No work is done against gas
(b) Heat is relased by the gas
(c) The internal energy of gas will increase
(d) Pressure does not change

44) When heat is given to a gas in an isothermal change, the result will be
(a) External work done
(b) Rise in temperature
(c) Increase in internal energy
(d) External work done and also rise in temp

45) The latent heat of vaporization of water is 2240 J/gm. If the work done in the process of expansion of 1 g is 168 J, then increase in internal energy is
(a) 2408 J (b) 2240 J
(c) 2072 J (d) 1904 J

46) The volume of an ideal gas is 1 litre and its pressure is equal to 72cm of mercury column. The volume of gas is made 900 cm^3 by compressing it isothermally. The stress of the gas will be
(a) 8 cm (mercury) (b) 7 cm (mercury)
(c) 6 cm (mercury) (d) 4 cm (mercury).

47) During an isothermal expansion of an ideal gas
(a) Its internal energy decreases
(b) Its internal energy does not change
(c) The work done by the gas is equal to the quantity of heat absorbed by it
(d) Both (b) and (c) are correct

48) If a cylinder containing a gas at high pressure explodes, the gas undergoes
(a) Reversible adiabatic change and fall of temperature
(b) Reversible adiabatic change and rise of temperature
(c) Irreversible adiabatic change and fall of temperature
(d) Irreversible adiabatic change and rise of temperature

49) In adiabatic expansion
(a) $\Delta U = 0$ (b) ΔU = negative
(c) ΔU = positive (d) ΔW = zero

50) Two identical samples of a gas are allowed to expand (i) isothermally (ii) adiabatically. Work done is
(a) More in the isothermal process
(b) More in the adiabatic process
(c) Neither of them
(d) Equal in both processes

51) Which is the correct statement
(a) For an isothermal change PV = constant
(b) In an isothermal process the change in internal energy must be equal to the work done
(c) For an adiabatic change $\frac{P_2}{P_1} = \left(\frac{V_2}{V_1}\right)^{\gamma}$ where γ is the ratio of specific heats
(d) In an adiabatic process work done

must be equal to the heat entering the system

52) Air in a cylinder is suddenly compressed by a piston, which is then maintained at the same position. With the passage of time
(a) The pressure decreases
(b) The pressure increases
(c) The pressure remains the same
(d) The pressure may increase or decrease depending upon the nature of the gas

53) When a gas expands adiabatically
(a) No energy is required for expansion
(b) Energy is required and it comes from the wall of the container of the gas
(c) Internal energy of the gas is used in doing work
(d) Law of conservation of energy does not hold

54) Compressed air in the tube of a wheel of a cycle at normal temperature suddenly starts coming out from a puncture. The air inside
(a) Starts becoming hotter
(b) Remains at the same temperature
(c) Starts becoming cooler
(d) May become hotter or cooler depending upon the amount of water vapor present

55) An adiabatic process occurs at constant
(a) Temperature (b) Pressure
(c) Heat
(d) Temperature and pressure

56) A given system undergoes a change in which the work done by the system equals the decrease in its internal energy. The system must have undergone an
(a) Isothermal change
(b) Adiabatic change
(c) Isobaric change (d) Isochoric change

57) During the adiabatic expansion of 2 moles of a gas, the internal energy was found to have decreased by 100 J. The work done by the gas in this process is
(a) Zero (b) –100 J
(c) 200 J (d) 100 J

58) A cycle tyre bursts suddenly. This represents an
(a) Isothermal process
(b) Isobaric process
(c) Isochoric process
(d) Adiabatic process

59) For adiabatic process, wrong statement is
(a) $dQ = 0$
(b) $dU = -dW$
(c) $Q =$ constant
(d) Entropy is not constant

60) A gas is being compressed adiabatically. The specific heat of the gas during compression is
(a) Zero (b) Infinite
(c) Finite but non-zero (d) Undefined

61) The process in which no heat enters or leaves the system is termed as
(a) Isochoric (b) Isobaric
(c) Isothermal (d) Adiabatic

62) $\Delta U + \Delta W = 0$ is valid for
(a) Adiabatic process
(b) Isothermal process
(c) Isobaric process
(d) Isochoric process

63) In adiabatic expansion of a gas
(a) Its pressure increases
(b) Its temperature falls
(c) Its density increases
(d) Its thermal energy increases

64) The internal energy of the gas increases in
(a) Adiabatic expansion
(b) Adiabatic compression
(c) Isothermal expansion
(d) Isothermal compression

65) We consider a thermodynamic system. If ΔU represents the increase in its internal energy and W the work done by the system, which of the following statements is true
(a) $\Delta U = -W$ in an adiabatic process
(b) $\Delta U = W$ in an isothermal process
(c) $\Delta U = -W$ in an isothermal process
(d) $\Delta U = W$ in an adiabatic process

66) A gas is compressed at a constant pressure of 50N / m 2 from a volume of 10m 3 to a volume of 4m 3. Energy of 100 J then added to the gas by heating Its internal energy is
(a) Increased by 400 J
(b) Increased by 200 J
(c) Increased by 100 J
(d) Decreased by 200 J

67) Which of the following is correct in terms of increasing work done for the same initial and final state

(a) Adiabatic < Isothermal < Isobaric
(b) Isobaric < Adiabatic < Isothermal
(c) Adiabatic < Isobaric < Isothermal
(d) None of these

68) A sample of gas expands from volume V_1 to V_2. The amount of work done by the gas is greatest when the expansion is
(a) Isothermal (b) Isobaric
(c) Adiabatic (d) Equal in all cases

69) Which of the following is a slow process
(a) Isothermal (b) Adiabatic
(c) Isobaric (d) None of these

70) In a reversible isochoric change
(a) $\Delta W = 0$ (b) $\Delta Q = 0$
(c) $\Delta T = 0$ (d) $\Delta U = 0$

71) Entropy of a thermodynamic system does not change when this system is used for
(a) Conduction of heat from a hot reservoir to a cold reservoir
(b) Conversion of heat into work isobarically
(c) Conversion of heat into internal energy isochorically
(d) Conversion of work into heat isochorically

72) The work done in which of the following processes is zero
(a) Isothermal process
(b) Adiabatic process
(c) Isochoric process (d) None of these

73) In which thermodynamic process, volume remains same
(a) Isobaric (b) Isothermal
(c) Adiabatic (d) Isochoric

74) Which is incorrect
(a) In an isobaric process, $\Delta p = 0$
(b) In an isochoric process, $\Delta W = 0$
(c) In an isothermal process, $\Delta T = 0$
(d) In an isothermal process, $\Delta Q = 0$

75) Which relation is correct for isometric process
(a) $\Delta Q = \Delta U$ (b) $\Delta W = \Delta U$
(c) $\Delta Q = \Delta W$ (d) None of these

76) The coefficient of performance of a Carnot refrigerator working between 30 °C and 0°C is
(a) 10 (b) 1 (c) 9 (d) 0

77) If the door of a refrigerator is kept open, then which of the following is true
(a) Room is cooled
(b) Room is heated
(c) Room is either cooled or heated
(d) Room is neither cooled nor heated

78) In a cyclic process, the internal energy of the gas
(a) Increases (b) Decreases
(c) Remains constant (d) Becomes zero

79) Irreversible process is
(a) Adiabatic process
(b) Joule-Thomson expansion
(c) Ideal isothermal process
(d) None of the above

80) In a cyclic process, work done by the system is
(a) Zero
(b) Equal to heat given to the system
(c) More than the heat given to system
(d) Independent of heat given to the system

81) An ideal heat engine exhausting heat at 77°C is to have a 30% efficiency. It must take heat at
(a) 127°C (b) 227°C (c) 327°C (d) 673°C

82) Efficiency of Carnot engine is 100% if
(a) $T_2 = 273$ K (b) $T_2 = 0$ K
(c) $T_1 = 273$ K (d) $T_1 = 0$ K

83) A measure of the degree of disorder of a system is known as
(a) Isobaric (b) Isotropy
(c) Enthalpy (d) Entropy

84) A scientist says that the efficiency of his heat engine which operates at source temperature 127°C and sink temperature 27°C is 26%, then
(a) It is impossible
(b) It is possible but less probable
(c) It is quite probable
(d) Data are incomplete

85) Even Carnot engine cannot give 100% efficiency because we cannot
(a) Prevent radiation
(b) Find ideal sources
(c) Reach absolute zero temperature
(d) Eliminate friction

86) "Heat cannot by itself flow from a body at lower temperature to a body at higher temperature" is a statement or consequence of
(a) Second law of thermodynamics
(b) Conservation of momentum
(c) Conservation of mass
(d) First law of thermodynamics

87) The first operation involved in a Carnot cycle is
(a) Isothermal expansion
(b) Adiabatic expansion
(c) Isothermal compression
(d) Adiabatic compression

88) For which combination of working temperatures the efficiency of Carnot's engine is highest
(a) 80 K, 60 K (b) 100 K, 80 K
(c) 60 K, 40 K (d) 40 K, 20 K

89) Which of the following processes is reversible
(a) Transfer of heat by radiation
(b) Electrical heating of a ni chrome wire
(c) Transfer of heat by conduction
(d) Isothermal compression

ANSWERS WITH EXPLANATION

1) (c)
2) (b) $\Delta Q = \Delta U + \Delta W$
$\Rightarrow \Delta U = \Delta Q - \Delta W = Q - W$ (using proper sign)
3) (b) $\Delta U = \Delta Q - W = 35 - 15 = 20\ J$
4) (c) Internal energy depends only on the temperature of the gas.
5) (b)
6) (d) $\Delta Q = \Delta W + \Delta U \Rightarrow 35 = -15 + \Delta U \Rightarrow \Delta U = 50J$
7) (a) $J\Delta Q = \Delta U + \Delta W$, $\Delta U = J\Delta Q - \Delta W$
$\Delta U = 4.18 \times 300 - 600 = 654$ Joule
8) (d) Work done = PDV which is state dependent as well as path dependent.
9) (a) $\Delta Q = 2k\ cal = 2 \times 10^3 \times 4.2J = 8400J$ and $\Delta W = 500J$
Hence from $\Delta Q = \Delta U + \Delta W$, $\Delta W = Q - \Delta U$ $8400 - 500 = 7900J$
10) (d) Change in internal energy (ΔU) depends upon initial an final state of the function while ΔQ and ΔW are path dependent also.
11) (b) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta W = \Delta Q - \Delta U$
$= 100 - 40 = 70J$
12) (b) Work done is not a thermodynamically function.
13) (c) $\Delta Q = \Delta U + \Delta W = 167 + 333 = 500\ cal$
14) (d) Heat always refers to energy in transit from one body to another because of temperature difference.
15) (d) Change in internal energy does not depend upon path so
$\Delta U = \Delta Q - \Delta W$ remain constant.
16) (b) $\Delta Q = \Delta U + \Delta W$ ∴ $\Delta Q = 200J$ and $\Delta W = -100J$
$\Rightarrow \Delta U = \Delta Q - \Delta W = 200 - (-100) = 300J$
17) (a) During free expansion of a perfect gas no, work is done and also no heat is supplied from outside. Therefore, no change in internal energy. Hence, temperature remain constant.
18) (b) From FLOT $\Delta Q = \Delta U + \Delta W$
∵ Heat supplied to the system so $\Delta Q \to$ Positive and work is done on the system so $\Delta W \to$ Negative Hence $+\Delta Q = \Delta U - \Delta W$
19) (a)
20) (d) State of a thermodynamic state cannot determine by a single variable (P or V or T)
21) (a) From FLOT
$\Rightarrow dU = dQ - dW \Rightarrow dU = dQ (< 0)$ (∵ $dW = 0$)
$\Rightarrow dU < 0$ So temperature will decrease
22) (d)
23) (a) Ideal gas possess only kinetic energy.
24) (b) The internal energy and entropy depend only on the initial and final states of the system and not on the path followed to attain that state.
25) (c) $\Delta Q = \Delta U + \Delta W = (U_f - U_i) + \Delta W$
$\Rightarrow 30 = (U_f - 40) + 10 \Rightarrow U_f = 60J$
26) (a) With rise in temperature, internal energy also increases.
27) (b) Heat supplied to a gas raise its internal energy and does some work against expansion, so it is a special case of law of conservation of energy.
28) (a)
29) (a)
30) (c)
31) (c) $\Delta W = P\Delta V$, here ΔV is negative so ΔW will be negative
32) (b) Entropy is related to second law of thermodynamics
33) (c) In isothermal process temperature remains constant.
34) (a) If isothermal curves cut each other then at equilibrium two temperature will be there which is impossible.

35) (c) In isothermal expansion temperature remains constant, hence no change in internal energy.

36) (b) $0.8 \times 5 = P \times (3+5) \Rightarrow P = 0.5\ m$

37) (c)

38) (a) $E_t = P$, if P = constant, E_t = constant

39) (c) No change in the internal energy of ideal gas but for real gas internal energy increases because work is done against intermolecular forces.

40) (c) This is the case of free expansion of gas. In free expansion $\Delta U = 0 \Rightarrow$ Temp. remains same.

41) (a) An isothermal process takes place at constant temperature, must be carried out in a vessel with conducting wall so that heat generated should go out at once.

42) (b) In isothermal process, temperature remains constant.

43) (b) In isothermal process, heat is released by the gas to maintain the constant temperature.

44) (a) In isothermal change, temperature remains constant. Hence $\Delta U = 0$.
Also from $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta Q = \Delta W$

45) (c) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = \Delta Q - \Delta W = 2240 - 168 = 2072\ J$

46) (a) For isothermal process $P_1V_1 = P_2V_2$

$$\Rightarrow P_2 = \frac{P_1V_1}{V_2} = \frac{72 \times 1000}{900} = 80\ cm$$

Stress $\Delta P = P_2 - P_1 = 80 - 72 = 8cm$

47) (d) During isothermal change T = constant $\Rightarrow \Delta U = 0$ also from FLOT, $\Delta Q = \Delta W$

48) (c) Gas cylinder suddenly explodes is an irreversible adiabatic change and work done against expansion reduces the temperature.

49) (b) In case of adiabatic expansion ΔW = positive and $\Delta Q = 0$
from FLOT $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = -\Delta W$
i.e., ΔU will be negative.

50) (a) In thermodynamic processes
Work done = Area covered by PV diagram with V-axis
From graph it is clear that $(Area)_{iso} > (Area)_{adi}$
$\Rightarrow W_{iso} > W_{adi}$



51) (a) Since $PV = RT$ and T = constant
$\therefore PV$ = constant

52) (a) Due to compression the temperature of the system increases to a very high value. This causes the flow of heat from system to the surroundings, thus decreasing the temperature. This decrease in temperature results in decrease in pressure.

53) (c) $\Delta Q = \Delta U + \Delta W = 0 \Rightarrow \Delta W = -\Delta U$
If ΔW is positive i.e., gas does work then ΔU should be negative meaning internal energy is used in doing work.

54) (c) Pressure is reduced, so the temperature falls.

55) (c) In adiabatic process, no heat transfers between system and surrounding.

56) (b) In adiabatic change Q = constant $\Rightarrow \Delta Q = 0$
So $\Delta W = -\Delta U$ ($\because \Delta Q = \Delta U + \Delta W$)

57) (d) For adiabatic process from FLOT
$\Delta W = -\Delta U$ ($\because \Delta Q = 0$)
$\Rightarrow \Delta W = -(-100) = +100J$

58) (d) The process is very fast, so the gas fails to gain or lose heat. Hence this process in adiabatic.

59) (d)

60) (a) $\Delta Q = mc\Delta\theta$. Here $\Delta Q = 0$. Hence $c = 0$

61) (d) In adiabatic process, no transfer of heat takes place between system and surrounding.

62) (a) In adiabatic process $\Delta Q = 0 \Rightarrow \Delta U + \Delta W = 0$ ($\because \Delta Q = \Delta U + \Delta W$)

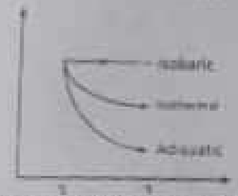
63) (b)

64) (b) In adiabatic process $\Delta U = -\Delta W$. In compression ΔW is negative, so ΔU is positive i.e. internal energy increases.

65) (a) According to the first law of thermodynamics $\Delta Q = \Delta U + \Delta W$
In adiabatic process $\Delta Q = 0$, hence $\Delta U = -\Delta W$

66) (a) From FLOT
$\Delta Q = \Delta U + \Delta W = \Delta U + P\Delta V$
$\Rightarrow 100 = \Delta U + 50 \times (4 - 10) \Rightarrow \Delta U = 400J$

67) (a) In thermodynamic process, work done is equal to the area covered by the PV curve with volume axis.
Hence, according to graph shown
$W_{adiabatic} < W_{isothermal} < W_{isobaric}$



68) (b) (Similar to previous question)
69) (a)
70) (a) $\Delta V = 0 \Rightarrow P\Delta V = 0 \Rightarrow \Delta W = 0$
71) (d) Entropy of a reversible process does not change
72) (c) $W = P\Delta V = 0$ (As $\Delta V = 0$)
73) (d)
74) (d) In isothermal process $\Delta Q \neq 0$
75) (a) For isochoric process
$\Delta V = 0 \Rightarrow \Delta W = 0$
From FLOT $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta Q = \Delta U$
76) (c) Coefficient of performance
$K = \frac{T_2}{T_1 - T_2} = \frac{273}{303 - 273} = \frac{273}{30} = 9$

77) (b) In a refrigerator, the heat dissipated in the atmosphere is more than that taken from the cooling chamber, therefore the room is heated if the door of a refrigerator is kept open
78) (c) Internal energy is a state function
79) (b)
80) (b) For cyclic forces $\Delta U = 0$ So, $\Delta Q = \Delta W$
81) (b) $\eta = 1 - \frac{T_2}{T_1} = \frac{30}{100} = 1 - \frac{350}{T_1}$
$\Rightarrow \frac{350}{T_1} = 1 - \frac{30}{100} = \frac{70}{100} = \frac{7}{10} \Rightarrow$
$T_1 = 500K = 227°C$
82) (b) $\eta = 1 - \frac{T_2}{T_1}$
for 100% efficiency $\eta = 1$ which gives $T_2 = 0$ K
83) (d)
84) (a) $\eta_{max} = 1 - \frac{T_2}{T_1} = 1 - \frac{300}{400} = \frac{1}{4} = 25\%$
85) (C)
86) (a)
87) (a)
88) (d) $\eta = 1 - \frac{T_2}{T_1}$; *for η to be max the ratio* $\frac{T_2}{T_1}$ *should be minimum*
89) (d) Slow isothermal expansion or compression of an ideal gas is reversible process, while the other given process is irreversible in nature.

For

- Exam preparation tips and tricks
- Mathematics tricks (mathematics used in physics)
- And much more

See last portion of our book for F.sc part 2 (Brilliant's series)